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THE USE OF A 3D-PRINTED DRILL GUIDE FOR THE INSERTION OF LUMBOSACRAL PEDICLE SCREWS - AN EX VIVO CADAVERIC STUDY

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Introduction

Degenerative lumbosacral stenosis (DLSS) is a common disease in large breed working dogs. Surgical intervention is recommended if the clinical signs cannot be relieved by conservative treatment. The surgical goals are to decompress the spinal cord and nerve roots and if indicated to provide an appropriate stability for bony fusion. Pedicle screw-rod fixation (PSRF) had been implemented to treat such instabilities in canine DLSS. Nevertheless, screw insertion remains difficult. Anatomical variations between individuals necessitate methods to optimize screw placement accuracy. Increased precision of implant positioning has been described in the human spine applying personalized 3D printed drill guides. However, the value of 3D printed drill guides has not yet been specifically described for the canine lumbar spine and lumbosacral junction. Therefore, the objectives of this ex vivo study were to evaluate the accuracy and feasibility of 3D printed drill guides for lumbar and sacral pedicle screw placement in dogs and to compare it with the free-hand technique using previously described trajectories for screw insertion. We hypothesized that 1) implant position as planned using a customized 3D-printed drill guide matches the surgical result, and 2) implant position using a 3D-printed drill guide leads to less complications and optimized implant position compared to free hand implanted pedicle screws.

Materials and methods

Lumbosacral vertebral specimens from nineteen dogs with a body weight of over 25 kg (mean 39.1 kg, range 26-60 kg) were included in this study. The specimens were stored at -18°C and thawed at room temperature 24 hours before use.

Surgical Procedure

Right and left side was randomly allocated into two treatment groups with either pedicle screw insertion as previously described (control group) or by applying a 3D printed costume made drill guide (guide group). Preoperative multislice CT scans were acquired for each specimen and stored in DICOM format. 3D planning and the development of the customize drill guide templates for the segments L5-L6 and L7-S1 were done 3D planning software (Materialise

GmbH V20.0, Munich, Germany). Optimal screw insertion trajectories were determined by one board certified surgeon. In addition to the two holes for drill bit insertion two holes for K-wire placement were planned for proper fixation of the guide on the bone surface. The drill guide templates were 3D printed with polylactic acid.

Surgery was performed by one board certified surgeon experienced with the implantation of PSRF in L7/S1 but not in L5/L6. The control group was always inserted first not to give any guidance in screw angulation and was performed as described using awl and probes. Soft tissues were dissected to fit the drill guide and PRSF canal was drilled using a 3.5mm drill. The drill guide was fixed on the specimen using 1.0mm K-wires in the dedicated drill guide canal. Pedicle screws were inserted and a postoperative CT scan was performed to assess screw position by two of the authors.

Image Parameters

Investigated parameters in the transverse plane included pre- and postoperative screw insertion angle (alpha), medial and lateral bone stock and vertebral canal penetration. Screw insertion angle (beta) and end plate penetration was assessed in the sagittal plane. The EP was subjectively evaluated using a 3D reconstruction of the bone surface. Screw insertion was classified as optimal (no vertebral canal penetration), acceptable (penetration of the medial vertebral canal bone cortex of less than a screw diameter of 4.5mm) or unacceptable (penetration of > 4.5mm).

Statistical Analysis

Paired t-test or Wilcoxon signed rank test were performed based on normal distribution of the data to compare measurements of angles and bone stocks between groups. Correlations were assessed using Spearman's rank correlation coefficient. P values of less than 0.05 were considered significant.

Results

Fourteen specimens had both L5-L6 and L7-S1 tested while four specimens had only L5-L6 and one only L7-S1 tested. The segments made up 132 inserted screws in total (60 L5-L6; 72 L7-S1) divided in the two treatment groups. Insertion angles of the pedicle screws placed with the 3D printed guide did not significantly differ between the preoperatively planned and postoperatively measured angles (alpha: p=0.355). Comparing the angle alpha between the 3D printed guide and the control group, a significant difference was only found in L7 (guided group: 19.6°, control group 14.9°; p=0.0012). No significant differences between the measured lengths of the medial and lateral bone stock in the guide and control group were calculated for the different vertebrae (p>0.139). A significant correlation of the angle alpha and the length of the bone stock was calculated in the 3D printed guide ($r = 0.356$) and the control group ($r = 0.377$).

Of the 66 screws inserted with a drill guide, seven were found to be malpositioned (10.6%), with one (0.7%) of these was found to be unacceptable. Screws inserted without a guide penetrated the vertebral canal in 28 out of 66 cases (42.4%), eight (5.3%) of these were found to be unacceptable confirmed by macroscopic dissection. The endplate was penetrated in two cases (3.0%) in the control group. In three vertebrae screws of both sides (guide and control) penetrated the vertebral canal. The number of penetrations in L5 and L6 were significantly higher in the control group in comparison to the 3D printed guide group ($p<0.034$). Subjectively assessed EP were correct in all but one control group side. In the drill guide group 87.4% (57/66) of the screws were classified as optimal while 53.0% (35/66) in the control group were assessed to be optimal.

Conclusion

In this study we showed that the application of customized 3D printed drill guides for pedicle screw insertion in lumbar vertebrae and the sacrum is a safe and accurate alternative to free hand pedicle screw placement, confirming both of our hypothesis.

A direct comparison of preoperatively planned insertion trajectories and postoperatively assessed screw position showed that pedicle screws can be placed precisely with customized 3D printed drill guides. Considering that dogs with DLSS are frequently presented with anatomical variants and degenerative or traumatic abnormalities, screw placement using recommended insertion angles and EPs may be associated with an increased risk for malpositioned screw.

In the control group an increased number of unacceptable screw placements were observed in lumbar vertebrae, especially L5 and L6, compared to S1. Complicating factors may be the missing insertion angle guidelines cranial to L7, less experience of the surgeon in this region and the limited pedicle's bone stock of the lumbar spine.

We conclude that a 3D printed drill guide increases safety for PRSF placement in the canine lumbosacral spine. Insertion angles as planned preoperatively using 3D software are comparable to the surgical result.

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